Parts Management Contributions to Manufacturing Readiness/Maturity

Parts Standardization and Management Committee Spring Conference
April 12-14, 2011

Institute for Defense Analyses
4850 Mark Center Drive • Alexandria, Virginia 22311-1882

Outline

- **Rationale for Selecting this Topic**
- **Background on Manufacturing Readiness/Maturity**
- **Parts Management Activities Impacting Manufacturing Readiness/Maturity**
- **Conclusions**

SE Goals for Parts Management

- **Ensure parts management is adequately reflected in SE policy and guidance**
- ***Exploit parts management contributions to manufacturing readiness***
- **Build on the parts management relationship to reliability, availability and maintainability (RAM)**
- **Conduct outreach on the importance and benefits of a proactive parts management approach**

This topic was included in the systems engineering goals for parts management that were established when DSPO became part of the systems engineering office

Manufacturing Policy and Guidance

- **Manufacturing risks recognized in DoDI 5000.02, Operation of the Defense Acquisition System**
  - **Established manufacturing-related exit criteria for acquisition phases**
- **Amplifying guidance included in the Systems Engineering (SE) section of the Defense Acquisition Guidebook (DAG)**
  - **Provided greater definition to the exit criteria defined in policy**
  - **Tied those definitions to the SE technical reviews**

GAO Interest in Manufacturing

- **GAO report 10-439 - 22 April 2010**
  - **In-depth assessment of Manufacturing Readiness Level (MRL) practices**
  - **Recommends requiring use of MRLs in DoD acquisition**
- **Collecting additional manufacturing-related data in its annual survey of acquisition programs**

Recent Congressional Focus on Manufacturing

~~Section 812 of the FY 2011 Authorization Act~~

- **MANAGEMENT OF MANUFACTURING RISK IN MAJOR DEFENSE ACQUISITION PROGRAMS**
  - **At a minimum, establish guidance that includes the following:**
    - **require the use of manufacturing readiness levels as a basis for measuring, assessing, reporting, and communicating manufacturing readiness and risk on major defense acquisition programs throughout the Department of Defense;**
    - **provide guidance on the definition of manufacturing readiness levels and how manufacturing readiness levels should be used to assess manufacturing risk and readiness in major defense acquisition programs;**
    - **specify manufacturing readiness levels that should be achieved at key milestones and decision points for major defense acquisition programs;**
    - **identify tools and models that may be used to manage and reduce risks that are identified in the course of manufacturing readiness assessments for major defense acquisition programs; and**
    - **require appropriate consideration of the manufacturing**

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Numerous Approaches to Assessing Manufacturing Maturity and Risk in Acquisition

- **Engineering Manufacturing Readiness Levels (EMRLs) used by the Missile Defense Agency**
- **Manufacturing questions in program support reviews**
- **Systems engineering technical review checklists**
- **Willoughby templates**
- **Manufacturing Readiness Levels**
  - **In development for over 10 years**
  - **Concerted, and most recent attempt to**

knowledge

It is clear that manufacturing risks should be assessed and managed throughout the acquisition process

Unofficial MRLs have been 10 Years in the Making

- **1999-2001:**
  - NCAT FCS Study first published MRL
  - Began integration with TRLs
- **2002-2003:**
  - MRL V2.0 (IPT)
  - Integrated into TRA Process, first as language defining CTEs, then as appendix
- **2004:**
  - JDMTP chartered WG, first Workshop on Matrix and Tools.
  - Primary use by Army
- **2005-2006:**
  - MRLs V3.0- MRA process developed, Air Force pilots it on S&T programs
  - First MRL Workshop on questions, V5.2
  - DSB 2006 “Manufacturing Technology Program: A Key to Affordably Equipping the Future Force”
- **2007-2008:**
  - MRL body of knowledge matures, second and third Workshops to finalize v7.0
  - DoD 5000.02 includes MRL language (2009 rewrite emphasis increases)
- **2009**:
  - Increased coordination with Systems Engineering, DPAP
  - Fourth/fifth joint Workshops with industry, V8.4
  - Industry adoption increases dramatically
- **2010**:

Status of MRL Use

- **Process well documented – MRL Deskbook**
  - **http://www.dodmrl.com**
- **Training available**
  - **AFIT course (SYS 213)**
  - **Some DAU courses**
- **Industry implementing as “Standard Operating Procedure”**
  - **Raytheon, Honeywell, GE, Lockheed, etc**
- **DoD implementation mixed**
  - **Air Force: Firm guidance to use MRLs at SAF, AFMC, AFRL, ASC, and AAC**
  - **Army: Firm guidance on ManTech programs &significant use in acquisition**
  - **Navy: No guidance, limited use on acquisition programs (NAVAIR is implementing MRLs)**

Because of the extensive maturity criteria developed and level of use, this briefing will use the MRL body of knowledge to relate parts management activities to manufacturing readiness

MRL Body of Knowledge Documented in *Unofficial* MRL Deskbook

- **Designed to provide**
  - **A manufacturing roadmap to address manufacturing maturity--developed by Industry and Government manufacturing SMEs**
  - **A tool that provides fact-based information on a program's manufacturing maturity**
    - **Essential for risk management**
  - **A forcing function to get manufacturing considerations addressed earlier in the design/development process**
  - **A tool for managing and communicating manufacturing maturity across the supply chain and customer base**

MRL Deskbook Table of Contents

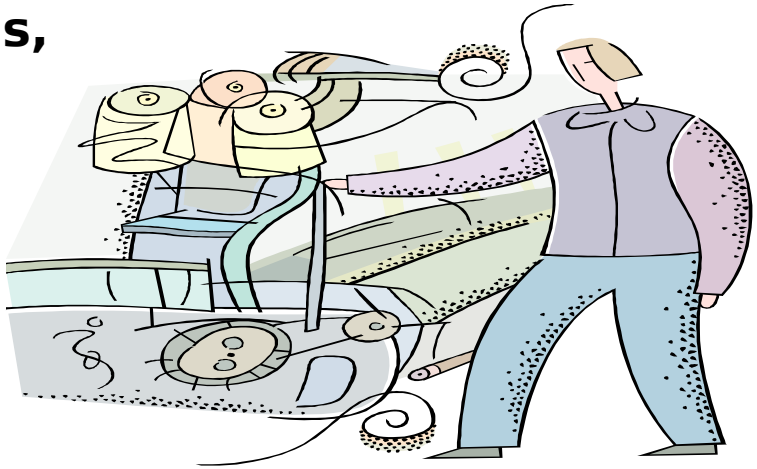
- **Section 1: Introduction**
- **Section 2: Manufacturing Readiness Levels**
- **Section 3: Manufacturing Readiness Levels and the Acquisition System**
- **Section 4: The Process for Conducting Assessments of Manufacturing Readiness**
- **Section 5: Manufacturing Maturation Plans and Risk Management**
- **Section 6: Applying Manufacturing**

Two conceptual elements – criteria for measuring manufacturing readiness and the process for managing the associated risk, this briefing deals solely with the criteria

Manufacturing Readiness Levels

Definitions

- **MRL 1: Basic Manufacturing Implications Identified**
- **MRL 2: Manufacturing Concepts Identified**
- **MRL 3: Manufacturing Proof of Concept Developed**
- **MRL 4: Capability to produce the technology in a laboratory environment**
- **MRL 5: Capability to produce prototype components in a production relevant environment**
- **MRL 6: Capability to produce a prototype system or subsystem in a production relevant environment**
- **MRL 7: Capability to produce systems, subsystems or components in a production representative environment**
- **MRL 8: Pilot line capability demonstrated; Ready to begin Low Rate Initial Production**
- **MRL 9: Low rate production demonstrated; Capability in place to begin Full Rate Production**
- **MRL 10: Full Rate Production**



Manufacturing Readiness Levels

Threads and Subthreads

1. **Technology and Industrial Base – industrial base issues, manufacturing technology development**
2. **Design -- producibility program, design maturity**
3. **Cost and Funding -- production cost knowledge (cost modeling), cost analysis, manufacturing investment budget**
4. **Materials (raw matls, components, subassys, subsystems) -- maturity, availability, supply chain management, special handling**
5. **Process Capability and Control -- modeling & simulation (product & process), mfg process maturity, process yields/rates**
6. **Quality Management to include supplier quality**
7. **Manufacturing Workforce to include engineering and production**
8. **Facilities to include tooling, special test equipment, and special inspection equipment**
9. **Manufacturing Management -- manufacturing**

Assessment Criteria

Acq Phase		Pre CR	Pre CR	Pre CR	CR - MS A	TD	MS B	SDD	MS C	LRIP - FRP	FRP
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
Technology & Industrial Base	**Technology Maturity**	Should be assessed at TRL 1.	Should be assessed at TRL 2.	Should be assessed at TRL 3.	Should be assessed at TRL 4.	Should be assessed at TRL 5.	Should be assessed at TRL 6.	Should be assessed at TRL 7	Should be assessed at TRL 7.	Should be assessed at TRL 8.	Should be assessed at TRL 9.
	Technology Transition to Production			Potential sources identified for technology needs. (Understand state of the art).	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Industrial Base assessed to identify potential manufacturing sources.	Industrial Capability Assessment (ICA) for MS B has been completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	Industrial capability to support production has been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.	Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk.	Industrial capability is in place to support start of FRP.	Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements.
	Manufacturing Technology Development		New manufacturing concepts and potential solutions identified.	Manufacturing technology concepts identified through experiments / models.	Mfg science & advanced mfg technology requirements identified.	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology efforts continuing. Manufacturing technology process improvement efforts initiated for FRP.	Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing.
Design	**Producibility Program**			Relevant materials/processes evaluated for manufacturability using experimental results.	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Required Test Evaluation Strategy (TES) includes Design for Test during production.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints. Manufacturing processes assessed for capability to test and verify in production, and influence on Operations & Support (O&S).	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. Design For Mfg Assembly) initiated.	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.	On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, Diminishing Mfg Sources & Material Shortages (DMSMS) and other changes assessed for producibility.
	Design Maturity	Manufacturing opportunities identified.	Applications defined. Broad performance goals identified that may drive manufacturing options.	Top level performance requirements defined. Trade-offs in design options assessed based on experiments. Product lifecycle and technical requirements evaluated.	Initial Systems Engineering Plan and Test and Evaluation Strategy recognize the need for the establishment/validation of manufacturing capability and management of manufacturing risk for the product lifecycle. Initial Key Performance Parameters (KPPs) identified.	Identification of enabling/critical technologies and components is complete and includes the product lifecycle. Evaluation of design Key Characteristics (KC) initiated.	Basic system design requirements defined. All enabling/critical technologies/components have been tested and validated. Product data required for prototype manufacturing released. A preliminary performance as well as focused logistics specification is in place. Key Characteristics and tolerances have been established.	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.	Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program.	Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KCs are controlled in production to 3-sigma or other appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled to 6-sigma or other appropriate quality levels.
	Production Cost Knowledge (Cost modeling)		Cost model approach defined.	Technology cost models developed for new process steps and materials based on experiments.	Detailed process chart cost models driven by key characteristics and process variables. Manufacturing, material and specialized reqt. cost drivers identified.	Detailed end-to-end value stream map cost model for major system components includes materials, labor, equipment, tooling/STE, setup, yield/scrap/rework, Work In Progress (WIP), and capability/capacity constraints. Component simulations drive	Cost model inputs include design requirements, material specifications, tolerances, integrated master schedule, results of system/subsystem simulations and production relevant demonstrations.	Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, and obsolescence solutions.	Engineering cost model driven by detailed design and validated with data from relevant environment.	Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact and potential for continuous improvement.	Cost model validated against actual FRP cost.

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Industrial Base Thread

- **Requires an analysis of the capability of the national technology and industrial base to support the design, development, production, operation, uninterrupted maintenance support of the system and eventual disposal (environmental impacts)**
  - **Establish the basis for maintaining a parts baseline, qualified by DoD, including a rationale approach to qualify suppliers, to change suppliers, and/or to switch parts**
  - **Evaluate whether there is a reasonable path to qualification by the suppliers including both development articles for design verification testing and qualification articles**
  - **Determine the extent to which there is a reliance on commercial products**

Design Thread

- **Requires an understanding of the maturity and stability of the evolving system design and any related impact on manufacturing readiness**
  - **Evaluate effects of part selection on all applications/duty cycles**
    - **All requirements should be considered**
    - **There will be excess capability for some applications**
  - **Ensure key design considerations given sufficient emphasis**
    - **Design for reliability (the system is only reliable as its weakest link)**
    - **Design to mitigate the effects of Pb-free electronics**
  - **Ensure processes are in place to avoid DoD identified prohibited design practices**
  - **Refine qualification considerations examined within the industrial base thread by evaluating**

Cost and Funding Thread

- **Requires an analysis of the adequacy of funding to achieve target manufacturing maturity levels. Examines the risk associated with reaching manufacturing cost targets**
  - **Ensure the preferred parts list (PPL) takes standardization into account to enhance control of PPL contents**
    - **Maximize the use of parts already being used elsewhere**
    - **Put process in place to discourage the use of new parts**
    - **Avoid the use of proprietary and sole source parts**
  - **Identify the funding needed to perform the activities necessary to determine the part will**

Materials Thread

- **Requires an analysis of the risks associated with materials (including basic/raw materials, components, semi-finished parts, and subassemblies)**
  - **Ensure the material selection process takes account of**
    - **The special handling and process maturity for Pb-free electronics parts**
    - **Corrosion prevention**
  - **Ensure proper flow down of requirements**
  - **Assess selected parts for availability and evaluate them to mitigate future DMSMS effects**
  - **Establish processes to minimize the use of prohibited components, materials, and processes and ensure proper parts specifications**
  - **Ensure qualification considerations have been properly implemented by identifying and performing tests and analyses for qualification of development articles and**

Process Capability and Control Thread

- **Requires an analysis of the risks that the manufacturing processes are able to reflect the design intent (repeatability and affordability) of key characteristics**
  - **Ensure there is an understanding of the consistency of the manufacturing process and that the process is sufficient to satisfy the system requirements**
  - **Ensure the performance of Pb-free products is sufficient for all applications and duty cycles**
  - **Ensure assembly and fabrication process selection are sufficient for all applications and duty cycles**

Quality Management Thread

- **Requires an analysis of the risks and management efforts to control quality and foster continuous improvement**
  - **Ensure quality requirements have been tailored for different suppliers**
    - **Consider both the product and its supply chain**
  - **Recommend part failure analysis approaches and evaluate effects on system performance including root cause identification and corrective action accountability**
  - **Ensure continuous improvement processes are being followed**
  - **Ensure proper controls have been established in product inspection and supplier selection to avoid the introduction of counterfeit parts**
  - **Minimize the impact of parts unavailability and industry changes on the production schedule**

Manufacturing Workforce Thread

- **Requires an assessment of the required skills, availability, and required number of personnel to support the manufacturing effort**
  - **No activities unique to parts management**

Facilities Thread

- **Requires an analysis of the capabilities and capacity of key manufacturing facilities (prime, subcontractor, supplier, vendor, and maintenance/repair)**
  - **No activities unique to parts management**

Manufacturing Management Thread

- **Requires an analysis of the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting program goals for affordability and availability)**
  - **Require contractors to develop a parts management plan tailored to the systems applications and duty cycles**
    - **Everything feeds into this**
  - **Ensure organizations and processes are in place to manage all critical processes**
  - **Coordinate with configuration and data management processes to ensure there is sufficient technical data and associated data rights**

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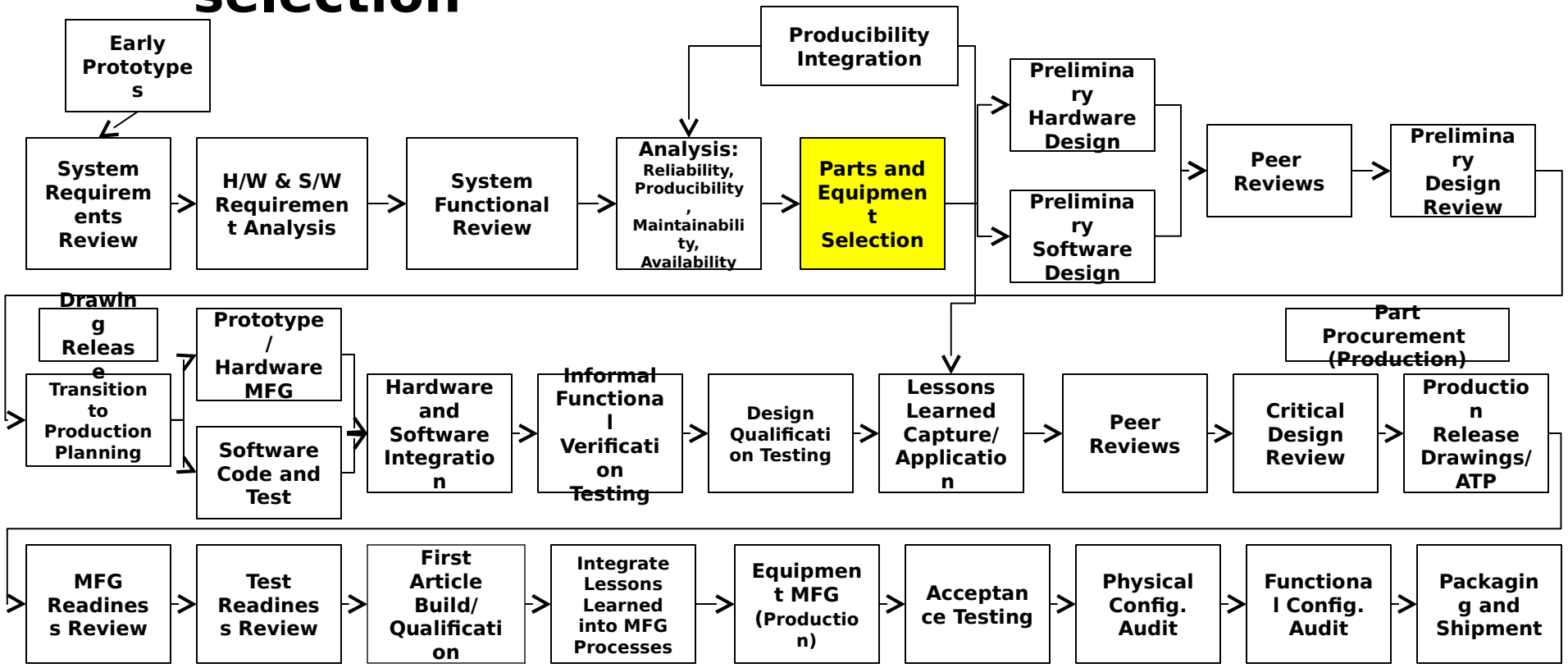
Observations (1 of 2)

- **Parts management is more than parts selection**

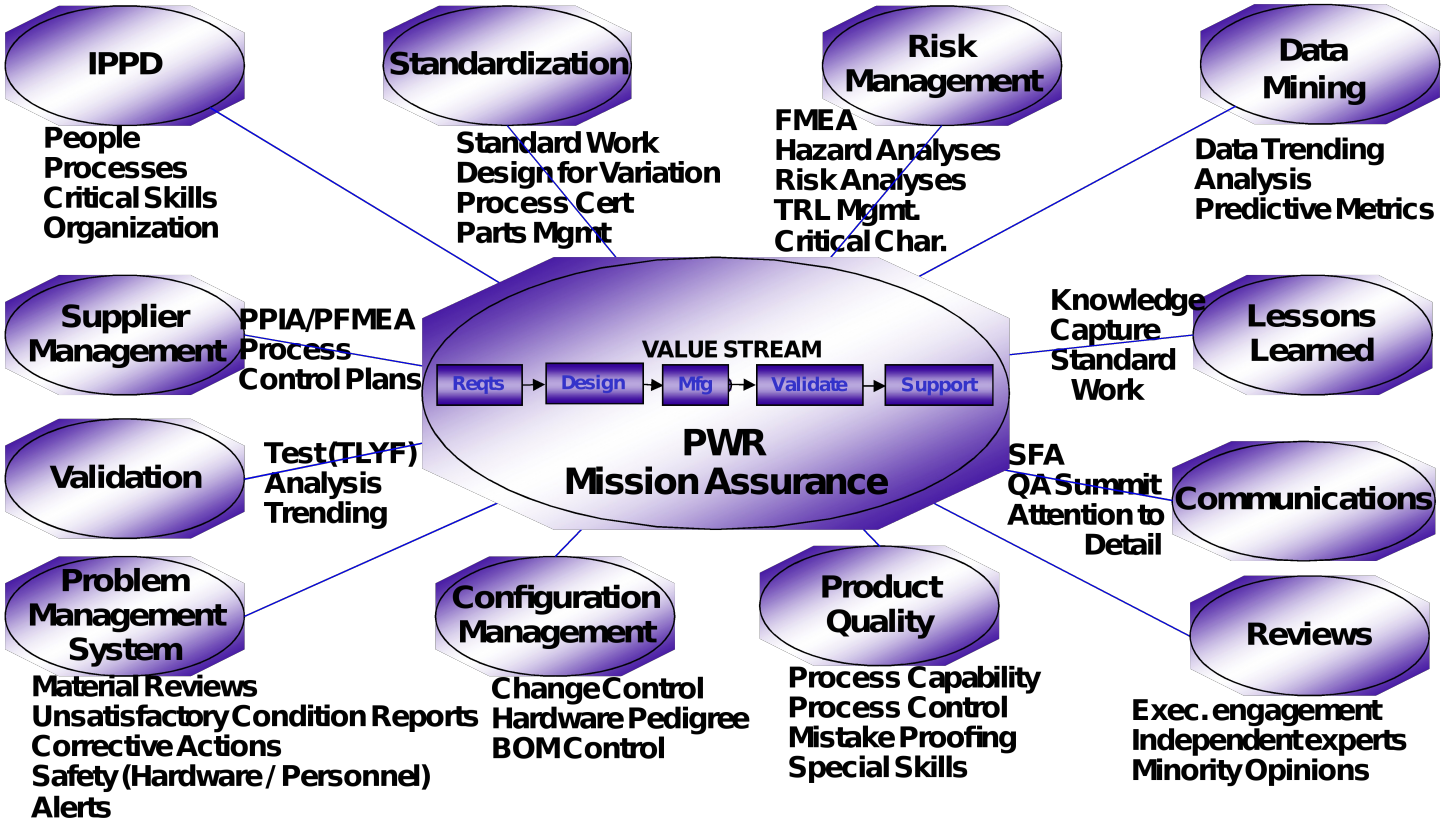


Adapted from: Frontier Electronics Systems

Observations (2 of 2)

- This presentation discussed how parts management activities contribute to the "greater whole" of manufacturing
  - Parts management activities cut across multiple manufacturing threads
  - These activities impact manufacturing maturity throughout the life cycle
- Other acquisition-related areas could have been used in lieu of manufacturing, depending on the current focus of an organization
  - Reliability is another important DoD initiative, and it was mentioned in the SE goals for parts management
  - How parts management activities are classified is situation dependent

Example of Parts Management Relationship to Mission Assurance



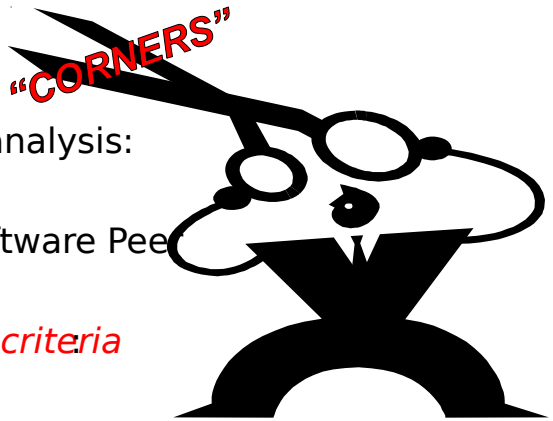
Used with permission: Pratt & Whitney Rocketdyne

Conclusions

- **Parts management is an integral and enabling part of many larger activities**
  - **It should not be treated as an independent function**
  - **It should not be neglected when an organization's focus evolves**
  - **It should not be neglected when problems occur**

Hurry up, you are behind schedule

- **DESIGN PROGRAMS**
  - Shortcut requirements analysis: Design Re-Spins
  - Compromise reliability / maintainability / availability analysis: Reduced Supportability
  - Reduce scope & content of Systems / Hardware / Software Peer Reviews: More Re-Spins
  - *Shortest lead time becomes principal parts selection criteria*
  - Increased obsolescence & counterfeit parts risks
  - Hardware–Software trade-off studies scope reduced: product design compromised
  - Reduced emphasis on Design for Manufacturing & Test: Production/Test Rework



Adapted from: Frontier Electronics Systems

Recommend Exploring Other Parts Management Relationships (1 of 2)

- **Relationship to reliability analysis, planning, and tracking**
- **Relationship to system engineering should be clarified since system engineering integrates all technical functions**
  - **Parts management considerations should be included in the systems engineering technical review checklists**
- **Relationship to trusted defense systems**
  - **Confidence**
  - **Integrity**
  - **Horizontal protection**

Recommend Exploring Other Parts Management Relationships (2 of 2)

- **Relationship to adaptable systems**
  - **Platform-based engineering**
  - **Model-based engineering**
    - **Concept models**
    - **Model-driven design**
    - **Model-driven manufacturing**
- **Relationship to development planning**
  - **Sets demand for technical analysis to support MDA's readiness determination to enter the acquisition process and proceed with an analysis of alternatives**

Recommend considering this material for incorporation into SD-19